

The effect of tone pulses with fluctuating inter-stimulus intervals on auditory evoked mismatch field (MMF)

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1 Introduction

We are interested in the capability of human extracting regularity from environmental stimuli, and are looking for the functional basis of this capacity and its location in the human brain [1]. In a power spectrum of the fluctuations expressed by $1/f^n$, n shows the steepness of the power spectrum. We investigated the effects of tone pulses with inter stimulus interval times given by three fluctuations, $1/f^0$, $1/f^1$ and $1/f^2$, and with a fixed interval ($1/f^\infty$) on the Magnetoencephalographic (MEG) auditory evoked Mismatch field (MMF). The MMF is a Magnetic Counterpart of Mismatch Negativity (MMN) [2,3,4], and the elicitation of the MMN is highly sensitive to the inter stimulus interval (ISI) [5].

There are two essential points concerning the elicitation of the MMF. The first necessary condition for the MMF elicitation is the production of a memory trace. The length of the ISI [5] and the probabilities of standard and deviant tones [6] are very important factors for producing the memory trace. The second point for the MMF elicitation is the destruction of the memory trace. The MMF is elicited by changing the physical features of the frequency; the intensity, the duration [7] or the spatial location [8] of the tone stimulus with the destruction of the memory trace. This study focused on the relationship between the exponent of the fluctuation and the production of the memory trace. We studied the effect of the exponent of the fluctuation in ISI on the elicitation of the MMF.

2 Subjects and methods

Subjects were four adults (four males; mean age ($\pm$ s.d.) 36.00 ± 6.16 years) with normal hearing and without neurological disorders. All subjects were right-handed.

The 64-channel whole-cortex type SQUID system (CTF Inc., Canada) was used to measure MEGs over the whole head. Electroencephalogram (EEG), was recorded simultaneously with MEG recording. The

relative position of the subject's head to that of the MEG sensors was determined using coils attached to three landmark points (the nasion and both the preauricular points) identical to those used in MRI.

All subjects received 630 presentations of two tones bursts. In a stimulus train, two tones, a standard tone (1000 Hz) with a probability of 80 %, and a deviant tone (2000 Hz) with a probability of 20%, were randomly presented to subjects binaurally. Each stimulus was of 95 msec duration, with a rise/decay time of 5 msec and an intensity of 60 dB sensation level. Four types of different ISI, the regular interval and the three irregular intervals fluctuating with $1/f^0, 1/f^1, 1/f^2$ patterns, were used. The fixed interval was 1.06 sec, and the fluctuation intervals were 1.06 sec on average ranging from 0.5 to 2.1 sec. The fluctuations $1/f^1$ and $1/f^2$ were generated by the program of Takayasu[9], producing non-integral Brownian motion, on a personal computer (NEC PC 9821). The fluctuation $1/f^0$ was generated from a white noise source with a NEC PC 9821. The 1000-Hz pure tones were produced with a multifunction generator, (1930A, NF ELECTRIC INSTRUMENTS, Japan). The random numbers were quantified to 9 steps, and changed in an inverse ratio between 0.4 and 2.0. The rise/decay time and the stimulus duration were controlled with a electronic switch (SB-104, LION, Japan) and a digital pulse generator (TG-04A, LION, Japan). The sound was delivered binaurally to the subjects, through plastic tubes (4.5m) terminating in high-quality insertable earphones (Cabot Inc., USA). The ISI was controlled with a NEC PC 9821 personal computer with a D/A converter, (CANOPS DAC-98, Japan).

Throughout the experimental session subjects whose eyes were closed, sat on a chair in a magnetically shielded room. They were instructed to relax and not to move or to blink eyes as far as possible.

MEGs and EEG were digitized every 1.6 ms at 12-bit accuracy for 499.2 ms, beginning 99.2 ms before stimulus onset, and were band passed through a 0.0-100.0Hz filter.

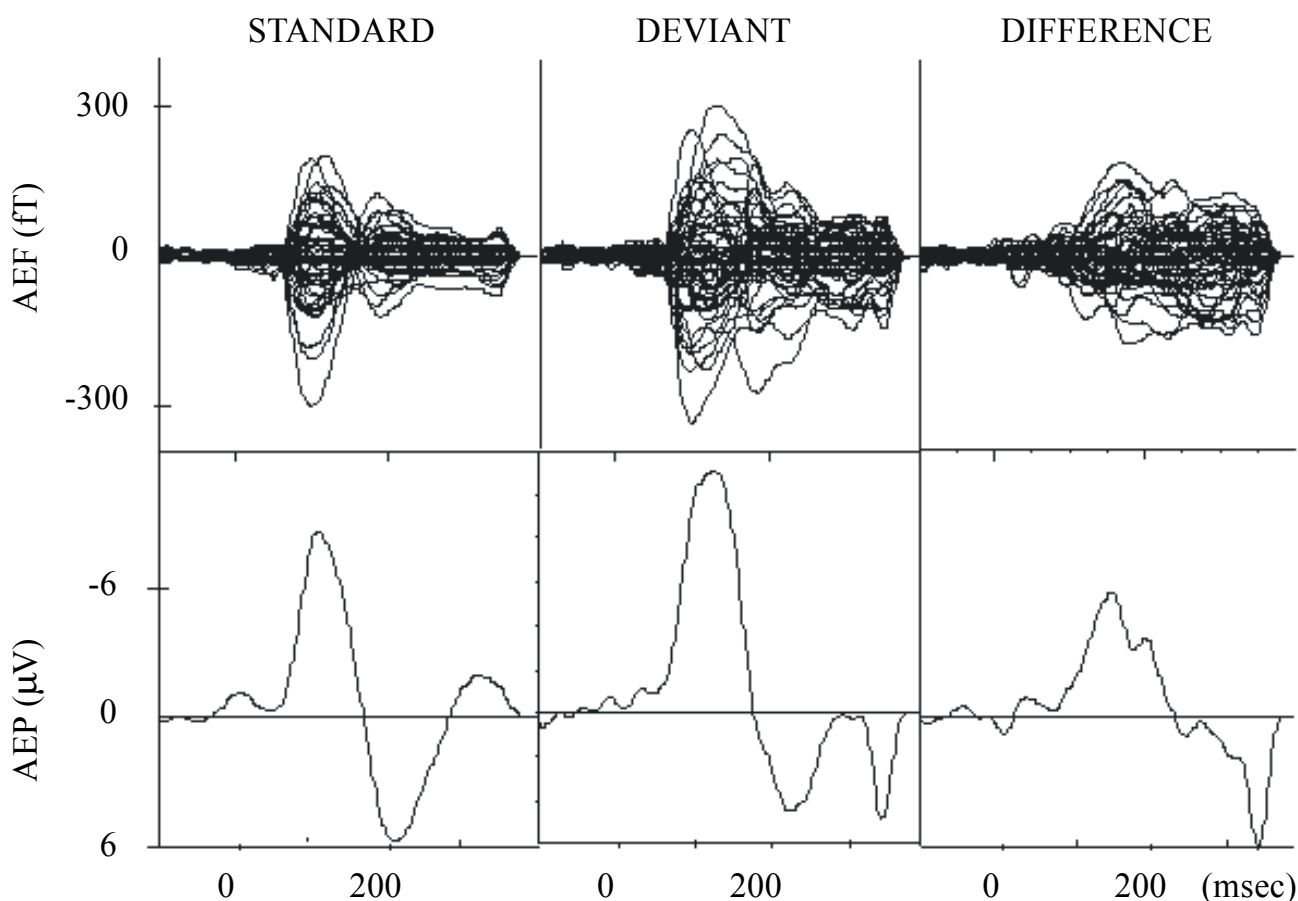


Figure 1: *The averaged waveforms of the auditory evoked field (AEF) of the magnetoencephalograph and the auditory evoked potential (AEP) of the electroencephalograph of the standard tones and the deviant tones, and the difference waves (the standard-tones AEF and AEP subtracted from the deviant tones AEF and AEP) of interstimulus interval with a fixed interval ($1/f^\circ$).*

Third-order spatial gradient environmental noise cancellation was applied, off-line digital bandpass filtering reduced the frequency range to 0-30 Hz, and the 504 responses to the standard tones and the 126 responses to the deviant tones were averaged. Eye movement artifacts were checked by monitoring the magnetic fields from the MEG sensors placed anteriorly. Three-dimensional MRI scans were obtained for all the subjects. EEG was recorded from a Cz (ten-twenty system) lead, referenced to linked earlobes using Ag/AgCl disk electrodes, (NE-155A, NIHON KODEN, Japan). All inter-electrode impedances were maintained below 5 k ohm. The EEG was amplified with a multi channel EEG amplifier (Neurotop MME-3132, NIHON KODEN, Japan), and filtered using high cut and low cut filters with cut-off frequencies of 100 Hz and 0.16 Hz. The T1-weighted MRI was obtained using a 1 Tesla MRI

System (MAGNETOM Impact Expert, SIEMENS, Germany).

The relationship between the exponent of the fluctuation and the root mean square (RMSQ) value of the difference waves of the MMF was examined for the four conditions.

3 Results

Fig. 1. shows the averaged wave forms of the auditory evoked field (AEF) of the Magnetoencephalograph and the auditory evoked potential (AEP) of the Electroencephalograph of the standard tones and the deviant tones, and the difference waves (the standard-tones AEF and AEP subtracted from the deviant tones AEF and AEP) of a fixed interval. The components of MMF and MMN of the difference waves were observed at the same latency.

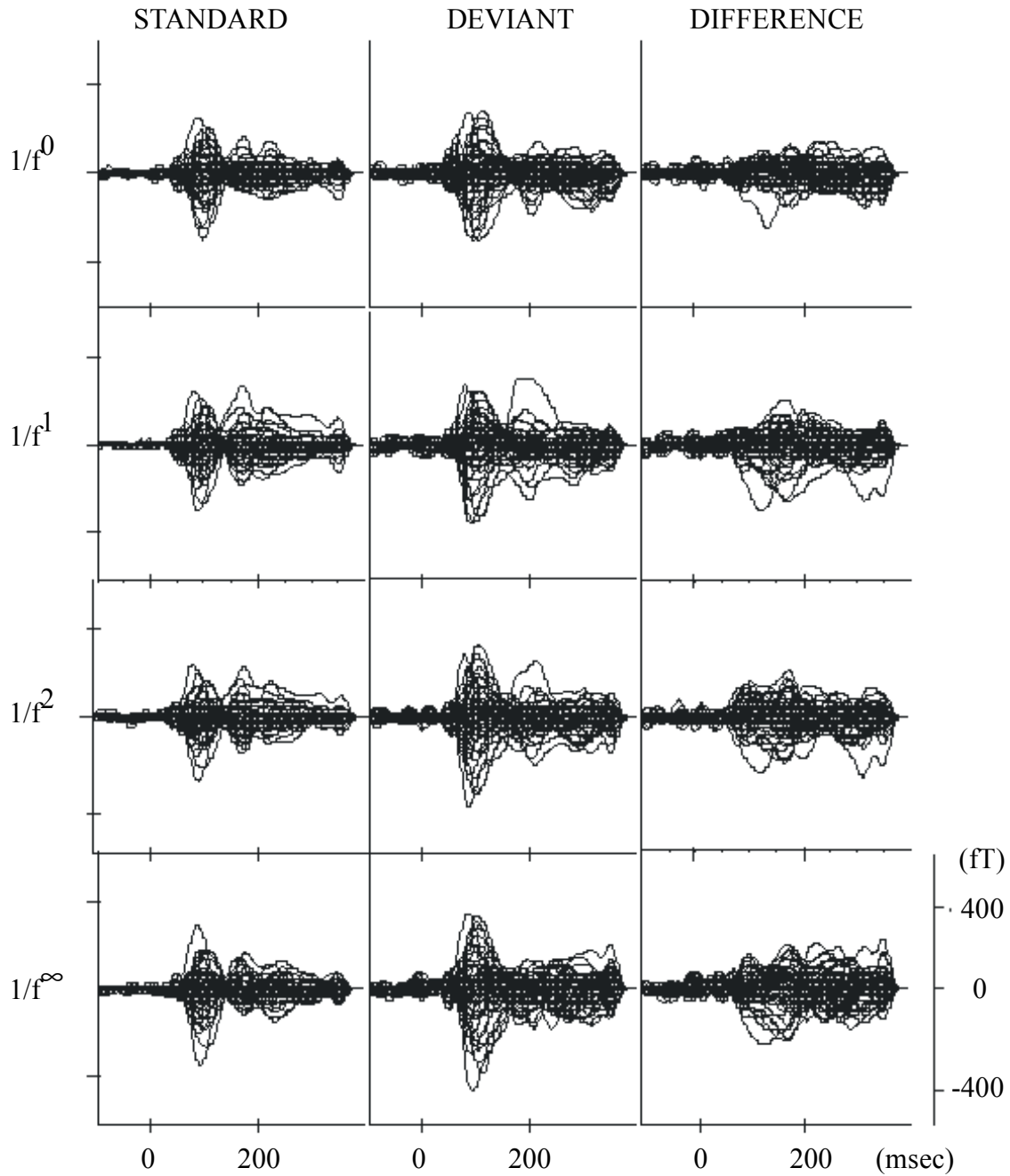


Figure 2: *The averaged waveforms of the auditory evoked field (AEF) of the magnetoencephalograph of the standard tones and the deviant tones, and the difference waves of interstimulus interval with fluctuation $1/f^0$, $1/f^1$, $1/f^2$ and with a fixed interval ($1/f^\infty$).*

Fig. 2. shows the averaged wave forms of the AEF for the standard tones and the deviant tones, and the difference waves of interstimulus interval with fluctuation $1/f^0$, $1/f^1$, $1/f^2$ and with a fixed interval ($1/f^\infty$). The progressive increment was observed for the amplitude of the difference waves as an increment of the exponent of fluctuation. The RMSQ value of the difference waves of the MMF

increased significantly with the exponent of fluctuation ($F(3/9)=4.757$; $p<0.05$) (Fig. 3).

4 Discussion

The physiological effects of fluctuations in tone were detected quantitatively as the RMSQ value of the MMF. The increment of the exponent of fluctuation enhanced the production of a memory trace, and the elicitation of the MMF.

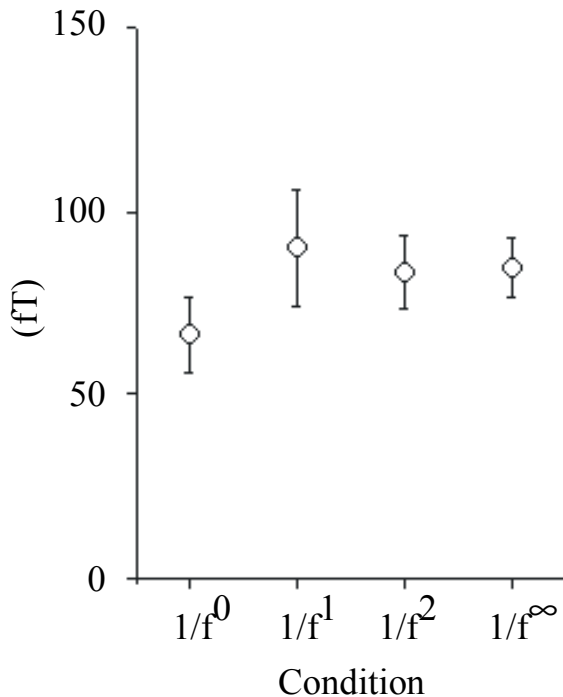


Figure 3: Relationship between the exponent of fluctuation and the RMSQ values of the difference waves of MMF. Each point is the mean with SD bar for 4 normal adult males.

The regularity of the fluctuation depended on the increase of the exponent of fluctuation. The increase of regularity of the stimulus on the fluctuation provoked an increase in the RMSQ value of the MMF. It implies that subjects detected the increase in the regularity of the stimulus fluctuation, and subsequently increased the RMSQ value of the MMF. The steepness of the slope marked the ratio of the increment of the RMSQ value of the MMF vs. the increment of the exponent of fluctuation. The ratio indicated the capacity of subjects to extract regularity from fluctuating stimulus.

The capacity to extract regularity from environmental stimuli was reflected in the elicitation of the MMF.

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